

TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

UT-0033

U S APPLICATION NO (IF KNOWN, SEE 37 CFR

10/009455

INTERNATIONAL APPLICATION NO
PCT/US00/12446

INTERNATIONAL FILING DATE
5 May 2000

PRIORITY DATE CLAIMED
7 May 1999

TITLE OF INVENTION

LINEAGE-RESTRICTED PRECURSOR CELLS ISOLATED FROM MOUSE NEURAL TUBE AND MOUSE EMBRYONIC STEM CELLS

APPLICANT(S) FOR DO/EO/US

MUJTABA, Tahmina and RAO, Mahendra S.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ has been communicated by the International Bureau.
 - c. ☒ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

- 1) Courtesy copy of the International Application;
- 2) Statement to support filing and submission in accordance with 37 CFR 1.821-1.825;
- 3) Return post card.

U.S. APPLICATION NO. (IF KNOWN), PCT/PTO <div style="font-size: 1.5em; font-weight: bold; text-align: center;">10/009455</div>		INTERNATIONAL APPLICATION NO. <div style="text-align: center;">PCT/US00/12446</div>		ATTORNEY'S DOCKET NUMBER <div style="text-align: center;">UT-0033</div>	
---	--	--	--	--	--

24. The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) : <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1040.00 <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$890.00 <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$740.00 <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$710.00 <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 <div style="text-align: right; font-weight: bold;">ENTER APPROPRIATE BASIC FEE AMOUNT =</div>				CALCULATIONS PTO USE ONLY <div style="border: 1px solid black; padding: 2px;">\$710.00</div>	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).				<div style="border: 1px solid black; padding: 2px;">\$0.00</div>	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	8 - 20 =	0	x \$18.00	\$0.00	
Independent claims	3 - 3 =	0	x \$84.00	\$0.00	
Multiple Dependent Claims (check if applicable). <input type="checkbox"/>				\$0.00	
TOTAL OF ABOVE CALCULATIONS =				\$710.00	
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				\$355.00	
SUBTOTAL =				\$355.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).				\$0.00	
TOTAL NATIONAL FEE =				\$355.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable). <input type="checkbox"/>				\$0.00	
TOTAL FEES ENCLOSED =				\$355.00	
				Amount to be:	\$
				refunded	
				charged	\$

a. ☐ A check in the amount of _____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 50-1619 in the amount of \$355.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-1619. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Jane Massey Licata, Registration No. 32,257
 Kathleen A. Tyrrell, Registration No. 38,350
 Licata & Tyrrell P.C.
 66 East Main Street
 Marlton, New Jersey 08053

Tel: 856-810-1515
 Fax: 856-810-1454

Jane Massey Licata
SIGNATURE

Jane Massey Licata
NAME

32,257
REGISTRATION NUMBER

November 7, 2001
DATE

LINEAGE-RESTRICTED PRECURSOR CELLS ISOLATED FROM MOUSE
NEURAL TUBE AND MOUSE EMBRYONIC STEM CELLS

Field of the Invention

The present invention relates to multipotent
5 neuroepithelial (NEP) stem cells, and lineage-restricted,
self-renewing precursor cells termed neuron-restricted
precursors (NRPs) and glial-restricted precursors (GRPs)
isolated from mouse neural tubes. Immunoselection against the
cell surface markers E-NCAM and A2B5 were used to isolate
10 mouse NRPs and GRPs, respectively. The present invention also
relates to lineage-restricted precursor cells isolated from
mouse embryonic stem cells (ES cells). As demonstrated
herein, mouse ES cell-derived NRPs are E-NCAM immunoreactive,
undergo self renewal in defined medium and differentiate into
15 multiple neuronal phenotypes in mass culture. Mouse ES cells
also generate A2B5 immunoreactive cells that are similar to
GRPs derived from mouse neural tubes and which differentiate
into oligodendrocytes and astrocytes. The present invention
also relates to methods for generating these lineage-
20 restricted precursors *in vitro* from mouse neural tubes and
cultured mouse ES cells.

Background of the Invention

Pluripotent stem cells in the central nervous system
(CNS) generate differentiated neurons and glia either directly
25 or through the generation of lineage-restricted intermediate
precursors (see e.g. Kilpatrick, T. J. and Bartlett, B. F. J.
Neurosci. 1995 15:3653-3661; Kilpatrick, T. J. and Bartlett,
B. F. Neuron 1993 10:255-265; Price et al. Brain Pathol. 1992
2:23-29; Reynolds et al. J. Neurosci. 1992 12:4565-4574;

- 2 -

Reynolds, B. A. and Weiss, S. Dev. Biol. 1996 175:1-13; Temple, S. and Davis, A. Development 1994 120:999-1008). Review of the relevant art indicates that different stem cells and lineage-restricted precursors with distinguishing characteristics and abilities are obtained depending upon the species, the region of the central nervous system from which the cells were obtained, and age of the animal from which the cells were obtained.

For example, multipotent neuroepithelial (NEP) cells have been shown to be present in the spinal cord of rats at embryonic day 10.5. These rat NEP cells are self-renewing cells that can differentiate into neurons, oligodendrocytes, astrocytes (Kalyani et al. Dev. Biol. 1997 186:202-223), and peripheral nervous system (PNS) derivatives (Mujtaba et al. Dev. Biol. 1998 200:1-15). Differentiation of rat NEP cells occurs via the generation of more restricted precursors. At embryonic day 13.5, two major types of lineage-restricted precursors are present in the rat: an E-NCAM immunoreactive neuronal precursor, termed NRP, that can generate multiple kinds of neurons but not oligodendrocytes or astrocytes (Mayer-Proschel et al. Neuron 1997 19:773-785; Kalyani et al. J. Neurosci. 1998 18:7856-7868); and an A2B5 immunoreactive glial precursor termed GRP, that can generate oligodendrocytes and astrocytes, but cannot generate neurons (Rao, M. S. and Mayer-Proschel, M. Dev. Biol. 1997 188:48-63; Mayer-Proschel et al. Neuron 1997 19:773-785; Rao et al. Proc. Natl. Acad. Sci. USA 1998 95:3996-4001).

U.S. Patent 5,753,506 by Johe et al. describes a different multipotential stem cell isolated from adult rat brain and regions of the embryonic rat brain including the cortex and striatum at embryonic day 14 and the hippocampus at embryonic day 16, as well as human fetal brain. This stem cell also undergoes self-renewal and can differentiate into neurons, astrocytes and oligodendrocytes upon culture in appropriate differentiation conditions. Cells isolated from

- 3 -

rat embryonic cortex and striatum at embryonic day 14 and rat embryonic hippocampus at embryonic day 16 were 70% pure. These cells can be maintained in the presence of FGF as well as EGF and/or TGF alpha. PDGF acts on these stem cells to bias neuronal differentiation.

Cattaneo and McKay (Nature 1990 347: 762) disclose a rat neuron-restricted precursor cell isolated from early embryonic brain, more specifically rat embryonic striatum primordia from embryonic day 13.5-14.5. A greater than 95% population of rat striatal cells expressing nestin is disclosed.

Gard et al. (Developmental Biology 1995 167:596) disclose a glial-restricted precursor cell isolated from the optic nerve of 4 day old rats which are bipotential, generating oligodendrocytes and A2B5⁺/GFAP⁺ astrocytes.

15 U.S. Patent 5,411,883 by Boss et al. teaches cells isolated from ventral mesencephalon tissue from porcine or human embryos at Carnegie stages 15-18. The porcine precursor cells are demonstrated to differentiate into dopaminergic neurons.

20 The existence of spinal cord NRPs in chick embryos has been demonstrated by retroviral tracing (Leber et al. J. Neurosci. 1990 10:1688-1697; Leber, S.M. and Sanes, J.R. J. Neurosci. 1995 15:1236-1248).

In addition, NRP cell lines that are E-NCAM
25 immunoreactive have been generated from human spinal cord
cultures.

Multipotent stem cells have also been identified in the mouse cortex in embryos between 12 and 18 days of gestation (Williams, B.P. and Price, J. *Neuron* 1995 14:1181-88); the telencephalon and mesencephalon of mice at embryonic day 10 and the cerebrum of mice at embryonic day 17 (Kilpatrick, T. J. and Bartlett, B. F. J. *Neurosci.* 1995 15:3653-3661); adult mouse thoracic spinal cord (Weiss et al. *J. Neurosci.* 1996 16:7599-7609); and adult and embryonic forebrain of the mouse (Weiss et al. *Trends Neurosci.* 1996 19:387-393).

- 4 -

An O-2A-like glial progenitor cell has also been identified in the optic nerve and cortex at late embryonic stages (reviewed in Collarini et al. J. Cell Sci. Suppl. 1991 15:117-123). U.S. Patent 5,688,692 by Jat discloses a method
5 for isolating a population of glial precursors from cortical cells derived from embryonic day 18 mice.

Neuronally restricted precursor cells from the juvenile subventricular zone (svz) of mice have also been identified by clonal analysis *in vivo* and *in vitro* (Young, G.M. and
10 Levison, S.W. Dev. Neurosci. 1996 18:255-265).

However, all of these cells differ significantly in growth factor requirements, culture conditions, and differentiation potential from rat NEP cells identified by Kalyani et al. (Dev. Biol. 1997 186:202-223) and rat GRP and
15 rat NRP cells identified by Mayer-Proschel et al. (Neuron 1997 19:773-785) and Kalyani et al. (J. Neurosci. 1998 18:7856-7868) and Rao, M. S. and Mayer-Proschel, M. (Dev. Biol. 1997 188:48-63), Mayer-Proschel et al. (Neuron 1997 19:773-785) and Rao et al. (Proc. Natl. Acad. Sci. USA 1998 95:3996-4001),
20 respectively.

Summary of the Invention

An object of the present invention is to provide an isolated, pure population of mouse neuron-restricted precursor cells derived from mouse neural tubes at embryonic day 12.0
25 or mouse embryonic stem cells by E-NCAM immunoreactivity. The mouse neuron-restricted precursor cells self-renew. Under differentiation conditions, these mouse NRP cells differentiate into neurons but not into glial cells.

Another object of the present invention is to provide
30 methods for isolating pure populations of the mouse neuron-restricted precursor cells. In one embodiment, a pure population of mouse neuron-restricted precursor cells is isolated by immunoselecting E-NCAM-immunoreactive cells from mouse E12.0 neural tube cells. In another embodiment mouse

- 5 -

embryonic stem cells are incubated under differentiation-inducing conditions so that the cells differentiate. E-NCAM-immunoreactive cells are then selected from the differentiating cells.

5 Another object of the present invention is to provide an isolated, pure population of mouse glial-restricted precursor cells derived from mouse neural tubes at embryonic day 12.0 or mouse embryonic stem cells by A2B5 immunoreactivity. The mouse glial-restricted precursor cells
10 self-renew. Under differentiating conditions, these mouse GRP cells differentiate into oligodendrocytes and at least two distinct populations of astrocytes, but not into neurons.

Another object of the present invention is to provide methods for isolating pure populations of the mouse glial-
restricted precursor cells. In one embodiment, a pure
population of mouse glial-restricted precursor cells is
isolated by immunoselecting A2B5-immunoreactive cells from
mouse E12.0 neural tube cells. In another embodiment, a pure
population of mouse glial-restricted precursor cells is
isolated by incubating mouse embryonic stem cells under
differentiation-inducing conditions so that the cells
differentiate and immunoselecting A2B5-immunoreactive cells
from the differentiating cells.

Another object of the present invention is to provide an isolated, pure population of mouse neuroepithelial stem cells derived from mouse neural tubes at embryonic day 8.5. These mouse neuroepithelial stem cells proliferate and self-renew in adherent feeder-cell-independent culture medium containing effective amounts of fibroblast growth factor and chick embryo extract. Under differentiating conditions, these mouse neuroepithelial stem cells differentiate into CNS neuronal cells, CNS glial cells including oligodendrocytes, A2B5-positive astrocytes, and A2B5-negative astrocytes, and neural crest stem cells.

- 6 -

Yet another object of the present invention is to provide a method of isolating a pure population of these mouse neuroepithelial stem cells. In this method, the neural tube from a mouse embryo is removed at embryonic day 8.5. Cells from the neural tube are dissociated and plated in a feeder-cell-independent culture on a substratum and in a medium containing fibroblast growth factor and chick embryo extract. The plated cells are then cultured at a temperature and in an atmosphere conducive to cell growth.

10 Detailed Description of the Invention

The present invention relates to purified neuroepithelial (NEP) cells, neuroblasts and glioblasts isolated from the developing mouse spinal cord and methods for isolating pure populations of these cells from the developing mouse spinal cord. The present invention also relates to pure populations of neuron- and glial-restricted precursor cells isolated from mouse embryonic stem (ES) cell cultures, as well as methods for isolating these cells from mouse ES cells. As demonstrated herein these cells exhibit characteristics similar to those described for rat neuronal precursor cells and different from previously described mouse neurosphere cells. In the present invention, E-NCAM immunoreactivity is used to isolate pure populations of differentiated mouse ES cells which generate multiple neuronal phenotypes, but which do not generate astrocytes or oligodendrocytes. A2B5 immunoreactivity is used to isolate pure populations of differentiated mouse ES which generate oligodendrocytes and astrocytes, but which do not generate neurons.

Mouse NEP cells of the present invention are different from classes of mouse stem cells described previously. The properties of mouse NEP cells of the present invention resemble those of rat NEP cells rather than other classes of stem cells isolated from other portions of the CNS and at different stages in development such as striatal embryonic

Growth factor dependence of E8.5 NEP cells was tested in
35 several growth factors at a variety of different

- 8 -

concentrations. FGF was sufficient to maintain NEP cell proliferation. In contrast, NGF, PDGF and EGF were ineffective at any dose tested. Further, none of the growth factors tested acted synergistically with FGF to alter cell division rates thus suggesting that EGF and PDGF are neither survival or proliferation factors for the mouse NEP cells of the present invention. The failure to see a response to EGF is indicative of these cells being a distinct population from both EGF dependent neurospheres and FGF/EGF dependent cells isolated from other regions and later stages in the mouse (Reynolds et al. J. Neurosci. 1992 12:4565-4574; Reynolds, B.A. and Weiss, S. Dev. Biol. 1996 175:1-13; and Weiss et al. J. Neurosci. 1996 16:7599-7609).

Differences of the E8.5 mouse NEP cells of the present invention were confirmed by examination of EGF-R expression in cell culture. EGF-R is not detected in the mouse NEP cells of the present invention. In contrast, EGF-R was readily detected in whole brain, as well as on glial precursors, neurons and astrocytes. Identical results were obtained using an antibody specific to mouse EGF-R. Accordingly, the cells of the present invention are clearly distinct from EGF dependent mouse neurospheres as well as FGF/EGF dependent mouse stem cells isolated at later stages of development.

The E8.5 mouse NEP cells of the present invention can also be maintained in defined medium with the addition of FGF for multiple passages (at least ten) and still be induced to differentiate by replating the cells on laminin or poly-L-lysine and reducing FGF concentrations. NEP cells under these conditions readily differentiated into neurons, astrocytes and oligodendrocytes. Thus, the mouse NEP cells are FGF dependent, grow in adherent culture and can generate CNS derivatives. In addition, these cells generate p75 immunoreactive crest cells, SMA immunoreactive smooth muscle cells and peripheral glial and neurons. PCR analysis also confirmed an increase in the expression of p75 when NEP cells

- 9 -

of the present invention were induced to differentiate into neural crest by the addition of 10 ng/ml of BMP-4. Neural crest and its derivatives have not been generated from EGF dependent stem cells.

5 Thus, results from these experiments indicate that at least during early time periods of development, only FGF dependent pluripotent stem cells are present in the developing mouse spinal cord. Taken together with evidence that at later stages an EGF or EGF/FGF dependent cell is present, it
10 is believed that at least two different classes of stem cells exist. Since the NEP cells of the present invention do not express EGF-R immunoreactivity, it is believed that EGF-R can serve as a marker for selection between these two different populations of stem cells.

15 As also demonstrated herein, E-NCAM and A2B5 immunoreactivity can be used to isolate lineage-restricted precursor cells from the mouse neural tube.

Differentiation in rat neural tubes has been shown to involve progressive restriction of cell fate (Mayer-Proschel
20 et al. Neuron 1997 19:773-785; Kalyani et al. J. Neurosci. 1998 18:7856-7868). Rat NEP cells generate more restricted multipotent precursors both *in vitro* and *in vivo* (Mayer-Proschel et al. Neuron 1997 19:773-785; Rao et al. Proc. Natl Acad. Sci. USA 1998 95:3996-4001). Two such restricted
25 multipotent precursors have been described: an E-NCAM immunoreactive neuronal precursor and an A2B5 immunoreactive glial precursor (Rao, M.S. and Mayer-Proschel, M. Dev. Biol. 1997 188:48-63; Rao et al. Proc. Natl Acad. Sci. USA 1998 95:3996-4001).

30 To determine if similar neuronal precursors could be isolated from mouse neural tubes, cells from mouse neural tubes at embryonic day 12.0 (E12.0) were analyzed for the presence of E-NCAM immunoreactive cells. A significant proportion of E12.0 neural tubes cells were E-NCAM
35 immunoreactive (ranging from 70-80% in three independent

- 10 -

experiments). Immunoselected E-NCAM⁺ cells divided in culture and expressed neuronal, but not glial, markers. Thus, based on their antigenic profile, E-NCAM immunoreactive cells appeared to be dividing neuron-restricted precursor cells.

5 To test the differentiation potential of E-NCAM immunoreactive cells, purified populations of E-NCAM⁺ cells were analyzed in mass and clonal culture. E-NCAM⁺ cells, when allowed to differentiate by addition of retinoic acid and reduction of FGF concentration, readily differentiated into
10 multiple kinds of neurons as assessed by RT-PCR and immunocytochemistry. Further, E-NCAM⁺ cells failed to differentiate into either oligodendrocytes or astrocytes when grown under glial promoting conditions, indicating that these cells are restricted or limited in their differentiation
15 potential.

Fura-2 Ca²⁺ imaging techniques were used to examine the ability of differentiated E-NCAM⁺ cells to respond to neurotransmitters and elevated K⁺. E12.0 E-NCAM⁺ cells were grown in culture for 10 days and allowed to differentiate.
20 They were then loaded with fura-2 and changes in internal Ca²⁺ concentrations in response to stimulus application were monitored. Most cells (>95%) responded to external application of glutamate or acetylcholine. Smaller fractions of cells responded to dopamine, GABA or glycine. A
25 substantial fraction of the cells responded to more than one neurotransmitter, demonstrating heterogeneity in the neuronal population derived from E-NCAM⁺ precursors. Further traces of internal Ca²⁺ changes were plotted over time for two different cells from the same clonally derived culture. While both
30 cells responded to glutamate, acetylcholine and high K⁺, one of the cells also responded to dopamine, indicating that the receptor expression profile of cells in the same culture varies. Thus, E-NCAM immunoreactive cells isolated from E12.0 mouse neural tube are neuron-restricted precursor cells that
35 can differentiate into a heterogeneous population of neurons,

- 11 -

and closely resemble their rat counterparts in antigenic characteristics, differentiation properties and growth potential.

Lineage-restricted glial precursors were also isolated from the developing mouse spinal cord at E12.0 via A2B5 immunoreactivity. A2B5 immunoreactive cells were isolated by immunopanning and mass cultures of cells were tested for cell division by BrdU incorporation. A significant proportion of these cells divided in culture, thus indicating that these are a mitotic population. The antigenic properties and differentiation potential of these cells was also examined. In contrast to rat glial restricted precursor cells, it was found that a small subset of the mouse A2B5 immunoreactive cells (<5%) were β -111 tubulin immunoreactive. This population was also E-NCAM immunoreactive as determined by immunopanning experiments. Thus, unlike rat spinal cord cultures, the A2B5 epitope was not uniquely present on glial cells.

To determine if the E-NCAM/ β -111 tubulin negative subset
20 of A2B5 cells represented glial precursors, this population
was examined by sequential panning. E-NCAM⁺ immunoreactive
cells were isolated and discarded and the E-NCAM⁻ population
was repanned to isolate A2B5 immunoreactive cells. Pooled
cells were analyzed by PCR and immunocytochemistry. A2B5⁺/E-
25 NCAM⁻ cells differentiated into oligodendrocytes and two kinds
of astrocytes but failed to differentiate into neurons when
grown under neuron promoting conditions thus indicating that
these cells are limited in their differentiation potential.
Accordingly, glial-restricted and neuron-restricted precursors
30 are both present in the developing mouse spinal cord and these
precursor cells can be distinguished by E-NCAM and A2B5
immunoreactivity.

Mouse ES cells have been shown to be capable of differentiating into neurons, astrocytes, and 35 oligodendrocytes. In addition, it has recently been

- 12 -

demonstrated that NEP-like cells can be harvested from ES cells, thereby bypassing the need to harvest NEP cells from fetal tissue. Accordingly, mouse ES cells cultures were analyzed to determine if more restricted neural precursors
5 that appear at developmentally later embryonic stages could be harvested in similar fashion.

In these experiments, the ES-D3 cell line, which has been shown to be able to contribute to all cell lineages, was obtained from ATCC and grown in non-differentiating (as
10 aggregates in DMEM/F12, 10% FCS and LIF 10 ng/ml and as adherent cultures on fibronectin coated dishes in NEP basal medium) and differentiating conditions (as adherent cultures on poly-L-Lysine/laminin substrate in NEP basal medium). Undifferentiated ES cells did not express E-NCAM
15 immunoreactivity, but upon aggregation and treatment with retinoic acid (RA), a subset (approx. 5%) of cells began to express E-NCAM immunoreactivity. E-NCAM⁺ cells were a mitotic population as assessed by BrdU incorporation. E-NCAM⁺ cells co-expressed MAP2, a marker for neurons (DeCamilli et al.
20 Neuroscience 1984 11:817-846) and β -III tubulin immunoreactivity, but did not express GFAP, GalC or O4 immunoreactivity. A subset of the E-NCAM cells were nestin immunoreactive, but none of the cells expressed GFAP, a glial marker. The co-expression of neuronal markers with E-NCAM and
25 the absence of glial markers indicate that ES cell derived E-NCAM⁺ immunoreactive cells are similar to E12.0 mouse neuronal restricted precursor cells.

To further confirm the neuronal differentiation of ES cell derived E-NCAM cells, ES cells were induced to
30 differentiate and E-NCAM immunoreactive cells were selected by immunopanning. Cells were grown in mass or clonal culture in medium supplemented with FGF and NT-3. When mass cultures of E-NCAM cells were induced to differentiate by withdrawal of FGF and the addition of RA, cells became postmitotic,
35 elaborated extensive processes and synthesized multiple

- 13 -

neurotransmitters. Immunocytochemistry and PCR analysis showed the presence of various excitatory, inhibitory and cholinergic neurotransmitters after differentiation. E-NCAM immunoreactive cells failed to differentiate into either
5 oligodendrocytes or astrocytes when grown under glial promoting conditions, indicating that these cells are limited in their differentiation potential. Thus ES cells can be used as a source of neuron-restricted precursor cells.

The differentiation potential of A2B5⁺/E-NCAM⁻ cells was
10 tested by inducing ES cells to differentiate and depleting E-NCAM immunoreactive cells by immunopanning. E-NCAM immunonegative cells were reselected for A2B5 immunoreactivity. This double selection procedure was utilized since, as described above, A2B5⁺ immunoreactivity has
15 been detected on glial precursors, as well as on subsets of neurons, from mice. A2B5 immunopositive cells were grown in mass or clonal culture in medium supplemented with FGF and PDGF. When mass cultures of A2B5⁺ cells were induced to differentiate by withdrawal of FGF, cells differentiated into
20 different glial populations. Two kinds of astrocytes could be identified as early as seven days after induction of differentiation. An A2B5⁺/GFAP⁻ flat astrocyte which appeared similar to astrocytes previously characterized as Type I astrocytes and a A2B5⁺/GFAP⁺ astrocyte which appeared similar
25 to type 2 astrocytes were detected in cultures. In addition, when cells were allowed to differentiate for longer time periods (10 days), oligodendrocyte differentiation was detected as assessed by GalC immunocytochemistry. A2B5 immunoreactive cells failed to differentiate into neurons when
30 grown under neuron promoting conditions, indicating that these cells are limited in their differentiation potential to glial lineages. The ability of ES cell derived A2B5 immunoreactive cells to differentiate into astrocytes and oligodendrocytes confirms their resemblance to E12.0 A2B5 derived GRP cells,
35 and indicates that like neuron-restricted precursors, glial

- 14 -

restricted precursors can be isolated directly from differentiating ES cell cultures.

Accordingly, provided in the present invention are pure populations of mouse neuroepithelial (NEP) cells isolated or
5 derived from mouse neural tubes at embryonic day 8.5 and mouse neuron- and glial-restricted precursor cells isolated or derived from mouse neural tubes at embryonic day 12.0 or mouse ES cells which exhibit similar characteristics to the rat NEP cells described by Kalyani et al. (Dev. Biol. 1997 186:202-
10 223) and rat GRP and rat NRP cells identified by Mayer-Proschel et al. (Neuron 1997 19:773-785) and Kalyani et al. (J. Neurosci. 1998 18:7856-7868) and Rao, M. S. and Mayer-Proschel, M. (Dev. Biol. 1997 188:48-63), Mayer-Proschel et al. (Neuron 1997 19:773-785) and Rao et al. (Proc. Natl. Acad.
15 Sci. USA 1998 95:3996-4001), respectively. For purposes of the present invention, by "pure" it is meant a population of cells in which greater than 95%, more preferably 99%, exhibit the same characteristics.

For example, as demonstrated herein, the mouse NEP cells of the present invention grow in adherent culture, do not exhibit EGF-R immunoreactivity, do not survive or proliferate in EGF and absolutely require FGF for both proliferation and survival. PDGF, an instructive molecule for cortical stem cells, had no observable effect either alone or in combination with FGF. Under differentiating conditions, the mouse NEP cells differentiate into CNS neuronal cells, CNS glial cells including oligodendrocytes, A2B5-positive astrocytes, and A2B5-negative astrocytes, as well as neural crest stem cells.

Like rat NRP cells, the mouse NRP cells are E-NCAM
30 immunoreactive. Further, E-NCAM appears to be expressed
exclusively by the NRP cells at this stage in development as
neither NEP cells nor glial precursors express E-NCAM epitopes
at E12.0 stage of development. Both mouse and rat cells also
proliferate in response to FGF-1 and 2 and can differentiate
35 into multiple classes of neurons. Some small differences in

- 15 -

proliferation and differentiation potential were noted as rat NRP cells appear more robust and survive over many more passages as compared to the more fragile mouse cell which could only be maintained for 10-12 passages. Further, rat NRP
5 cells appear to be more heterogeneous as assessed by Ca^{2+} imaging (Kalyani et al. J. Neurosci. 1998 18:), while mouse cells show less heterogeneity and appear to mature more slowly.

Mouse GRP cells of the present invention, like rat GRP
10 cells, generate oligodendrocytes and two kinds of astrocytes ($A2B5^+/GFAP^+$ and $A2B5^+/GFAP^-$). Like rat GRPs and unlike O-2A cells, mouse GRPs respond to CNTF by differentiating into astrocytes rather than oligodendrocytes.

Also provided in the present invention are methods for
15 isolating pure populations of these mouse NEP from mouse neural tubes at embryonic day 8.5, as well as methods for isolating pure populations of the mouse NRP and GRP cells from mouse neural tubes at embryonic day 12.0 or from differentiating mouse embryonic stem cells.

20 To isolate pure populations of mouse NEP cells, the neural tube from a mouse embryo at embryonic day 8.5 is removed. To isolate pure populations of mouse NRP or GRP cells, the neural tube from a mouse embryo at embryonic day 12.0 is removed. In both methods, cells from the neural tube
25 are then dissociated in accordance with well known procedures such as is described in Example 2. The dissociated cells are then plated onto fibronectin coated cell culture plates in a medium containing fibroblast growth factor and chick embryo extract. The plated cells are then cultured at a temperature
30 and in an atmosphere known to be conducive to growth of most cells.

Cells grown from the mouse neural tube removed at embryonic day 8.5 comprise a pure population of mouse NEP cells.

The ability to isolate and grow purified populations of these mouse cells has multiple utilities. For example, these cells can be used in mouse models to develop new transplantation techniques, as well as therapeutically in humans for transplantation in diseases characterized by

- 17 -

neuronal and/or glial degeneration. These cells are also useful in identifying new drugs which enhance survival and proliferation of these cells upon transplantation.

The cells of the present invention can also be used in the identification of genes specific to selected stages of development. In one embodiment, the cells can serve as a source of mRNA for generation of cDNA libraries that are specific to the stage development of the cells.

The cells can also be used in the generation of cell-specific antibodies for use therapeutically and diagnostically.

The following nonlimiting examples are provided to further illustrate the present invention.

EXAMPLES

15 Example 1: Substrate preparation

Fibronectin (Sigma) was diluted to a concentration of 20 $\mu\text{g/ml}$ in distilled H_2O (Sigma). Fibronectin solution was applied to tissue culture dishes for a minimum of 4 hours. Laminin (Biomedical Technologies Inc.), used at a
20 concentration of 20 $\mu\text{g/ml}$, was dissolved in DPBS (Gibco-BRL). To prepare fibronectin-laminin double coated dishes, laminin was applied to fibronectin coated dishes and plates were incubated overnight at 4° . Excess laminin was withdrawn and the plates were rinsed with medium.

25 Example 2: Mouse cell cultures

Mouse C57BI6 embryos were removed at embryonic day 8.5 and placed in a petridish containing DPBS (Gibco-BRL). The trunk segments of embryos were enzymatically treated with collagenase (Worthington; 10 mg/ml) and dispase (Boehringer Mannheim; 20 mg/ml) for 10 minutes at room temperature. The enzyme solution was replaced with fresh medium with 10% chick embryo extract. The trunk segments were gently triturated to release the spinal cords from surrounding tissue. The spinal cords were then incubated in 0.05% trypsin solution for 5 minutes at 37°C. The cells were dissociated and plated in 35

- 18 -

mm fibronectin coated dishes as mass cultures (5000 cells/dish). Cells were maintained at 37°C in 5% CO₂/95% air in NEP basal medium and 10% CEE (Chicken Embryo Extract).

The NEP basal medium used in all experiments described
5 herein is a chemically defined medium modified from that described by Stemple, D.L. and Anderson, D.J. (Cell 1992 71:973-985). The medium consists of DMEM-F12 (Gibco-BRL) supplemented with additives described by Bottenstein, J.E. and Sato, G. (Proc. Natl. Acad. Sci. USA. 1979 76:514-517) and
10 bFGF (25 ng/ml). The NEP complete medium is NEP basal medium with 10% CEE (Chicken Embryo Extract).

Mouse C57B6 embryos were removed at embryonic day 12.0 and placed in a petridish containing DPBS. Spinal cords were mechanically dissected from surrounding connective tissue
15 using sharpened No. 5 forceps. Isolated spinal cords were incubated in 0.05% trypsin solution for 30 minutes. The trypsin solution was replaced with fresh medium. The spinal cords were gently triturated with a pasteur pipette to dissociate the cells. The dissociated cells were plated on
20 fibronectin/laminin coated dishes. Cells were maintained at 37° in 5% CO₂/95% air in NEP complete medium.

Differentiation into neural crest was promoted by adding BMP-4 (10 ng/ml) to the mouse NEP cells growing on fibronectin for a period of 4 days. The cells were then replated on
25 fibronectin/laminin coated dishes in neural crest medium [NEP basal medium supplemented with bFGF (10 ng/ml), NGF (50 ng/ml), EGF (100 ng/ml)]. To promote maturation into Schwann cells, dibutyl CAMP (5 µm/ml, Sigma) was added for an additional 7 days. To promote smooth muscle differentiation,
30 crest cells were grown in neural crest medium supplemented with 10% fetal bovine serum (Hyclone, Utah).

Example 3: ES cell cultures

Undifferentiated ES-D3 cells (ATCC) were grown as aggregates in suspension dishes (Nunc) in DMEM-F12 with 10%
35 FCS and LEF (Leukemia Inhibitory Factor, 10 ng/ml) for 4 days.

- 19 -

The medium was then changed to NEP basal medium and the cells were plated on fibronectin. The medium was changed every 2 days. Differentiation into NRPs and GRPs was induced by plating the cells on poly L-Lysine/laminin double coated dishes. For long term neuronal differentiation FGF was withdrawn and Retinoic acid (Sigma) was added to the medium. Similarly for long term glial induction, cells were maintained in PDGF (10 ng/ml) and T3 (30 nm) with the withdrawal of FGF.

Example 4: Immunopanning of E-NCAM⁺ and A2B5⁺ cells

10 E-NCAM⁺ and A2B5⁺ cells were purified from dissociated E 12.0 neural tube cells using a specific antibody capture assay (Wysocki, L. J., and Sato, V. L. Proc. Natl. Acad. Sci. USA 1978 75:2844-2848) with minor modifications. Specifically, the cells were trypsinized and 10 ml of cell suspension (Basal 15 medium and 20% FCS) was plated on a 100 mm petridish and incubated at 37°C in a 5% CO₂ humidified atmosphere for 2-3 hours for the maximum attachment of flat cells. The supernatant, containing an enriched population of neuronal and oligodendrocyte cells, was plated on dishes coated with either 20 E-NCAM antibody (5A5, Developmental Studies Hybridoma Bank (DSHB), 1:1 dilution) or A2B5 antibody (ATCC, 1:1 dilution) to allow binding of all E-NCAM⁺ and A2B5⁺ cells. E-NCAM and A2B5 dishes were prepared by sequentially coating petridishes with an unlabeled antimouse IgM antibody (10 µg/ml) overnight, 25 rinsing 3x with DPBS, followed by incubation with E-NCAM or A2B5 hybridoma, supernatants for 1-3 hours at room temperature. Cells were allowed to bind to the dish for 1 hour at room temperature. The supernatant was discarded and the dish was washed 8x with DPBS. The bound cells were 30 mechanically scraped off and plated on fibronectin/laminin coated dishes in 1 ml of NEP basal medium either as mass (5000 cells/dish) or clonal (100 cells/dish) cultures. Growth factors were added every other day. In all cases, an aliquot of cells was tested for panning efficiency by 35 immunocytochemistry. In general, the panning efficiency was

- 20 -

greater than 90%. For E-NCAM panned OR NRP cultures, the NEP basal medium was supplemented with the following growth factors; NT3, PDGF, BDNF, and FGF (all at 10 ng/ml). For A2B5 panned or GRP cultures, the NEP basal medium was supplemented
5 with PDGF (10 ng/ml), and FGF (10 ng/ml).

Example 5: Immunocytochemistry

Staining procedures were in accordance with procedures described by Rao, M. S. and Mayer-Proschel, M. (Dev. Biol. 1997 188:48-63). Staining for the cell surface markers p75,
10 E-NCAM, and GalC was carried out in cultures of living cells. To stain cells with antibodies against cytoplasmic antigens, cultures were fixed with 2% formaldehyde for 20 minutes at room temperature.

In general, dishes were incubated with primary antibody
15 for one hour followed by incubation with an appropriate secondary antibody for 30 minutes. Double labeling experiments were performed by simultaneously incubating cells in appropriate combinations of primary antibodies followed by non-crossreactive secondary antibodies. DAPI histochemistry
20 was performed as described by Kalyani et al. (Dev. Biol. 1997 186:202-223). DAPI (Sigma) staining was generally done after labeling had been completed. p75, E-NCAM, A2B5, and GalC were hybridoma supernatants obtained from DSHB. β -111 tubulin (Sigma), which stains neurons, nestin (monoclonal obtained
25 from DSHB; polyclonal obtained from Signal Pharmaceuticals), a marker for undifferentiated stem cells (Zimmerman et al. Neuron 1994 12(6): following 1388; Lendahl et al. Cell 1990 60:585-595; and Dahlstrand et al. Dev. Brain Res. 1995 84:109-129), MAP2 (Sigma), another neuronal marker were used as
30 described previously. Antibodies to glutamate and glycine were obtained from Signature Immunologicals and used as per manufacturer's recommendations. Antibodies to GFAP and GAD were obtained from Chemicon and used at 1:500 dilution.

- 21 -

Example 6: BrdU incorporation

To assess the proliferation of neuronal and oligodendrocyte precursor cells, 5 bromo-2'deoxyuridine (BrdU, Sigma) at a concentration of 10 μ m was added to the cells for 5 24 hours. The cells were then fixed with 2% paraformaldehyde for 15 minutes at room temperature followed by 95% ethanol for 30 minutes at -20°C. Cells were then washed 3x with PBS and 5% goat serum, and permeabilized with 2N HCl for 10 minutes. Acid was removed by 3 washes with PBS and 5% goat serum and 10 the residual HCl was neutralized with 0.1 M sodium borate for 10 minutes. After rinsing with PBS cells were incubated with anti-BrdU antibody (1: 100, Sigma) for 30 minutes at room temperature in buffer containing 0.5% TRITON X-100. The cells were then incubated with goat anti-mouse IgG (1:100, Jackson 15 Immunologicals) for 30 minutes. After 3 washes with PBS, the cells were observed with a Zeiss Fluorescence microscope.

Example 7: RNA extraction and cDNA synthesis

Total RNA was isolated from cells or neural tubes by a modification of the guanidinium-isothiocyanate extraction 20 method (TRIZOL, Gibco-BRL). cDNA was synthesized using 1-5 μ g of total RNA in a 20 μ l reaction. Superscript II (Gibco-BRL), a modified Maloney murine leukemia virus reverse transcriptase and oligo (dT) 12-18 primers were used, and the Gibco-BRL protocol was followed.

25 Example 8: Polymerase Chain Reaction

Aliquots of cDNA, equivalent to 1/20 of the above reaction, were used in a 50 μ l reaction volume. PCR amplification was performed using Elongase polymerase (Gibco-BRL). Primer sequences and cycling temperatures used for PCR 30 amplification of receptors are shown in the following Table. The reactions were run for 35 cycles and a 10 minute incubation at 72°C was added at the end to ensure complete extension.

- 22 -

Gene	Product (bp)	Primers (5' to 3') Sense (top); Antisense (bottom)	SEQ ID NO:
p75	329	GCACATACTCAGACGAAGCCA AGCAGCCAAGATGGAGCAATAGAC	1 2
ChAT	377	CTGAATACTGGCTGAATGACATG AAATTAATGACAACATCCAAGAC	3 4
Isl-1	350	GCAGCATAGGCTTCAGCAAG GTAGCAGGTCCGCAAGGTG	5 6
GAD ₆₅	327	GAATCTTTTCTCCTGGTGGTG GATCAAAGCCCCGTACACAG	7 8
Calbindin28	276	GCAGAATCCACCTGCAG GTTGCTGGCATCGAAAGAG	9 10
Glutaminase	560	GCACAGACATGGTTGGGATACTAG GCAGGGCTGTTCTGGAGTCG	11 12
Cyclophilin	302	CCACCGTGTTCTTCGACATC GGTCCAGCATTTGCCATGG	13 14
EGF-R	205	GCTGGGGAAGAGGAGAGGAGA ACGAGTGGTGGGCAGGTGTCTT	15 16
FGFR-1	764	TGGGAGCATCAACCACACCTACC GCCCGAAGCAGCCCTCGCC	17 18
FGFR-4	672	ATCGGAGGCATTCGGCTGCG AGAACTGCCGGGCCAAAGGG	19 20
PLP/DM20	505/400	GACATGAAGCTCTCACTGGCAC CATAATTCTGGCATCAGCGC	21 22
MAP2	404	GAAGGAAAGGCACCACACTG GCTGGCGATGGTGGTGGG	23 24
NF-M	186	GCCGAGCAGACCAAGGAGGCCATT CTGGATGGTGTCTCTGGTAGCTGCT	25 26
GFAP	346	TTGCAGACCTCACAGACGCTGCGT CGGTTTTCTTCGCCCTCCAGCAAT	27 28

Example 9: Intracellular Ca²⁺ Measurement

Calcium imaging experiments were performed on clonal cultures of E-NCAM panned cells obtained from mouse E8.5 embryos as described above. Cells were loaded with 5 μ M Fura-2 AM (Sigma, Grynkiewicz et al., 1985) plus pluronic F127

- 23 -

(Sigma, 80 $\mu\text{g/ml}$) in rat Ringer's solution (RR) at 23°C in the dark. Following the 20 minute incubation, cells were washed three times in RR and allowed to de-esterify for 30 minutes. Relative changes in intracellular Ca^{2+} concentrations were measured from the background-corrected ratio of fluorescence intensity by excitation at 340/380 nm. A response was defined as a minimum rise of 10% of the ratioed baseline value. A Zeiss-Attofluor imaging system and software (Atto Instruments Inc.) were used to acquire and analyze the data. Data points were sampled at 1 Hz. Neurotransmitters (100 μM concentration) were made fresh in RR and delivered by bath exchange using a small volume loop injector (200 μl). RR consisted of (in mM): 140 NaCl, 3 KCl, MgCl_2 , 2 CaCl_2 , 10 HEPES, and 10 glucose. Ascorbic acid (500 μM) was added to dopamine solutions to prevent oxidation. Control application of 500 μM ascorbic acid had no effect. The pH of all solutions was adjusted to 7.4 with NaOH. High K^+ RR was made by substituting 50 mM K^+ for Na^+ in the normal RR.

- 24 -

What is Claimed is:

1. An isolated, pure population of mouse neuron-restricted precursor cells derived from mouse neural tubes at embryonic day 12.0 or mouse embryonic stem cells by E-NCAM
5 immunoreactivity.

2. A method for isolating a pure population of the mouse neuron-restricted precursor cells of claim 1 comprising:

(a) incubating mouse embryonic stem cells under differentiation-inducing conditions so that the cells
10 differentiate; and

(b) isolating a pure population of mouse neuron-restricted precursor cells by immunoselecting E-NCAM⁺ immunoreactive cells from the differentiated cells.

3. A method for isolating a pure population of the
15 mouse neuron-restricted precursor cells of claim 1 comprising:

(a) removing a neural tube from a mouse embryo at embryonic day 12.0;

(b) dissociating cells from the neural tube;

(c) plating the dissociated cells in a feeder-cell-
20 independent culture on a substratum and in a medium containing fibroblast growth factor and chick embryo extract;

(d) culturing the plated cells at a temperature and in an atmosphere conducive to cell growth; and

(e) isolating a pure population of mouse neuron-
25 restricted precursor cells by immunoselecting E-NCAM-immunoreactive cells from the cultured, plated cells.

4. An isolated, pure population of mouse glial-restricted precursor cells derived from mouse neural tubes at embryonic day 12.0 or mouse embryonic stem cells by A2B5⁺
30 immunoreactivity.

- 25 -

5. A method for isolating a pure population of the mouse glial-restricted precursor cells of claim 4 comprising:

(a) incubating mouse embryonic stem cells under differentiation-inducing conditions so that the cells
5 differentiate; and

(b) isolating a pure population of mouse glial-restricted precursor cells by immunoselecting A2B5-immunoreactive cells from the differentiated cells.

6. A method for isolating a pure population of the
10 mouse glial-restricted precursor cells of claim 4 comprising:

(a) removing a neural tube from a mouse embryo at embryonic day 12.0;

(b) dissociating cells from the neural tube;

(c) plating the dissociated cells in a feeder-cell-
15 independent culture on a substratum and in a medium containing fibroblast growth factor and chick embryo extract;

(d) culturing the plated cells at a temperature and in an atmosphere conducive to cell growth; and

(e) isolating a pure population of mouse glial-restricted
20 precursor cells by immunoselecting A2B5-immunoreactive cells from the cultured, plated cells.

7. An isolated, pure population of mouse neuroepithelial stem cells derived from mouse neural tubes at embryonic day 8.5 which proliferate and self renew in adherent
25 feeder-cell-independent culture medium containing fibroblast growth factor and chick embryo extract.

8. A method of isolating a pure population of the mouse neuroepithelial stem cells of claim 7 comprising:

(a) removing a neural tube from a mouse embryo at
30 embryonic day 8.5;

(b) dissociating cells from the neural tube;

- 26 -

(c) plating the dissociated cells in a feeder-cell-independent culture on a substratum and in a medium containing fibroblast growth factor and chick embryo extract; and

(d) culturing the plated cells at a temperature and in
5 an atmosphere conducive to cell growth to obtain a pure population of mouse neuroepithelial stem cells.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : C12N 1/00, 5/06, 5/10		A1	(11) International Publication Number: WO 00/68359
			(43) International Publication Date: 16 November 2000 (16.11.00)
<p>(21) International Application Number: PCT/US00/12446</p> <p>(22) International Filing Date: 5 May 2000 (05.05.00)</p> <p>(30) Priority Data: 60/133,159 7 May 1999 (07.05.99) US</p> <p>(71) Applicant (for all designated States except US): UNIVERSITY OF UTAH RESEARCH FOUNDATION [US/US]; 210 Park Building, Salt Lake City, UT 84112 (US).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): MUJTABA, Tahmina [US/US]; 11205 South 465 East, Sandy, UT 84070 (US). RAO, Mahendra, S. [US/US]; 4590 S. Parkhill Drive, Salt Lake City, UT 84124 (US).</p> <p>(74) Agents: LICATA, Jane, Massey et al.; Law Offices of Jane Massey Licata, 66 E. Main Street, Marlton, NJ 08053 (US).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report.</p>	
<p>(54) Title: LINEAGE-RESTRICTED PRECURSOR CELLS ISOLATED FROM MOUSE NEURAL TUBE AND MOUSE EMBRYONIC STEM CELLS</p> <p>(57) Abstract</p> <p>Isolated, pure populations of mouse neuroepithelial stem cells, mouse neuron-restricted precursor cells, and mouse glial-restricted precursor cells derived from mouse embryonic neural tubes are provided. Also provided are isolated, pure populations of mouse neuron-restricted precursor cells, and mouse glial-restricted precursor cells derived from mouse embryonic stem cells. In addition, methods for isolating pure populations of these cells from either mouse embryonic neural tubes or mouse embryonic stem cells are provided.</p>			

Docket No.
UT-0033

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Lineage-Restricted Precursor Cells Isolated From Mouse Neural Tube and Mouse Embryonic Stem-Cells

the specification of which,

(check one)

☐ is attached hereto.

☒ was filed on 5 May 2000 as United States Application No. or PCT International Application Number PCT/US00/12466 and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

60/133,159
(Application Serial No.)

(Application Serial No.)

(Application Serial No.)

(Application Serial No.)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Status)
(patented, pending, abandoned)

Patent and Trademark Office-U.S. DEPARTMENT OF COMMERCE

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*



26259

PATENT TRADEMARK OFFICE

Send Correspondence to:

Direct Telephone Calls to: *(name and telephone number)*

Jane Massey Licata or Kathleen A. Tyrrell - (856) 810-1515

Full name of sole or first inventor Tahmina Mujtaba	
Sole or first inventor's signature	Date
Residence Midvale, Utah	
Citizenship Pakistan	
Post Office Address 6993 Well Wood Road, Apt. 3J	
Midvale, Utah 84047	

200

Full name of second inventor, if any Mahendra S. Rao	
Second inventor's signature	Date <i>3/18/02</i>
Residence Timonium, Maryland MD	
Citizenship India U.S.	
Post Office Address 8 Breezy Tree Court, #D	
Timonium, Maryland 21093	

Docket No.
UT-0033

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Lineage-Restricted Precursor Cells Isolated From Mouse Neural Tube and Mouse Embryonic Stem-Cells

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 5 May 2000 as United States Application No. or PCT International Application Number PCT/US00/12466 and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

60/133,159

May 7, 1999

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)



Send Correspondence to:

Direct Telephone Calls to: (name and telephone number)
Jane Massey Licata or Kathleen A. Tyrrell - (856) 810-1515

100

Full name of sole or first inventor Tahmina Mujtaba	
Sole or first inventor's signature <i>Tahmina J. mujtaba</i>	Date <i>3-18-02</i>
Residence Midvale, Utah UT	
Citizenship Pakistan	
Post Office Address 6993 Well Wood Road, Apt. 3J	
Midvale, Utah 84047	

Full name of second inventor, if any Mahendra S. Rao	
Second inventor's signature	Date
Residence Timonium, Maryland	
Citizenship India	
Post Office Address 8 Breezy Tree Court, #D	
Timonium, Maryland 21093	

PCT/US00/12446
JC07 Rec'd PCT/PTO 05 NOV 2001
10/009455

<110> Mujtaba, Tahmina
Rao, Mahendra S.
University of Utah Research Foundation

<120> Lineage-Restricted Precursor Cells Isolated from Mouse
Neural Tube and Mouse Embryonic Stem Cells

<130> UT-0025

<140>
<141>

<150> 60/133,159
<151> 1999-05-07

<160> 28

<170> PatentIn Ver. 2.1

<210> 1
<211> 21
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Synthetic

<400> 1
gcacatactc agacgaagcc a

<210> 2
<211> 24
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Synthetic

<400> 2
agcagccaag atggagcaat agac

<210> 3
<211> 23
<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 3

ctgaatactg gctgaatgac atg

23

<210> 4

<211> 23

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 4

aaattaatga caacatccaa gac

23

<210> 5

<211> 20

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 5

gcagcatagg cttcagcaag

20

<210> 6

<211> 19

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 6

gtagcaggtc cgcaagggtg

19

<210> 7

<211> 21

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 7

gaatcttttc tcctggtggt g

21

<210> 8

<211> 21

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 8

gatcaaaagc cccgtacaca g

21

<210> 9

<211> 18

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 9

gcagaatccc acctgcag

18

<210> 10

<211> 19

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 10

g ttgctggca tcgaaagag

19

<210> 11

<211> 24

<212> DNA

WO 00/68359

PCT/US00/12446

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 11

gcacagacat ggttgggata ctag

24

<210> 12

<211> 20

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 12

gcagggtgt tctggagtcg

20

<210> 13

<211> 20

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 13

ccaccgtgtt cttcgacatc

20

<210> 14

<211> 19

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 14

ggtccagcat ttgccatgg

19

<210> 15

<211> 21

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 15

gctggggaag aggagaggag a

21

<210> 16

<211> 22

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 16

acgagtgggtg ggcaggtgtc tt

22

<210> 17

<211> 23

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 17

tgggagcatc aaccacacct acc

23

<210> 18

<211> 19

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 18

gcccgaagca gccctcgcc

19

<210> 19

<211> 20

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 23

gaaggaaagg caccacactg

20

<210> 24

<211> 18

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 24

gctggcgatg gtggtggg

18

<210> 25

<211> 24

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 25

gccgagcaga ccaaggaggc catt

24

<210> 26

<211> 24

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 26

ctggatggtg tcctggtagc tgct

24

<210> 27

<211> 24

<212> DNA

WO 00/68359

PCT/US00/12446

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 27

ttgcagacct cacagacgct gcgt

24

<210> 28

<211> 24

<212> DNA

<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Synthetic

<400> 28

cggttttctt cgccctccag caat

24